NBSIR 75-788

# Evaluation of the Fire Hazard in a Mobile Home Resulting from an Ignition on the Kitchen Range

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Center for Fire Research
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Interim Report

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U.S. DEPARTMENT OF COMMERCE, Elliot L. Richardson, *Secretary*
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NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

# EVALUATION OF THE FIRE HAZARD IN A MOBILE HOME RESULTING FROM AN IGNITION ON THE KITCHEN RANGE

Edward K. Budnick and David P. Klein

Abstract

A series of fire tests was conducted in a mobile home of typical construction. The purpose of these tests, which were completed in March 1975, was to evaluate the potential fire hazard resulting from an accidental ignition from cooking on the kitchen range. Specific attention was directed to (a) the ease of ignition of the overhead kitchen cabinets as a function of the clearance between the range and the underside of the cabinets with and without the presence of a metal hood, and (b) the flame spread following the ignition.

The tests, in which a preheated pan of cooking oil was used as an ignition source, were conducted in a mobile home kitchen area. The materials tested were printed lauan plywood, printed particle board, and molded polystyrene, which are representative of materials used in kitchen cabinet construction in mobile homes.

Under the test conditions employed, it was found that while the time to ignition of the cabinet materials was only slightly affected by the clearance between the cabinet bottom and the range, a significant time delay or no ignition resulted from the installation of a metal range hood.

An additional problem area revealed by the tests was the ignition and burn-through of the wall partition directly behind the range.

Specific design recommendations based on test results are presented along with suggestions for further investigation.

Key words: Fire test; flame spread; kitchen cabinets; kitchen range; kitchen range hood; limited combustibility; mobile home.

## 1. INTRODUCTION

This series of fire tests was conducted as part of a comprehensive mobile home fire safety project with the overall objective being to obtain experimental data on the potential growth and spread of fire in mobile homes as affected by factors which include interior finish, room layout, and location of ignition. All of these considerations play an important role in the kitchen area where the cooking range, as well as other energy consuming kitchen appliances, provide potential sources of ignition. It has been estimated that 25 percent of mobile home fires originate in the kithcen [1][1].

The objective of this test series was to evaluate the possible fire hazard due to the proximity to the cooking range of a number of types of overhead kitchen cabinets. The testing was divided into 3 phases, each of which was conducted in the kitchen area of an actual 12 x 65 foot (30.5 x 19.8 meter) mobile home. The floor plan is shown in figure 1.

[1]Numbers in brackets refer to the literature references listed at the end of this paper.

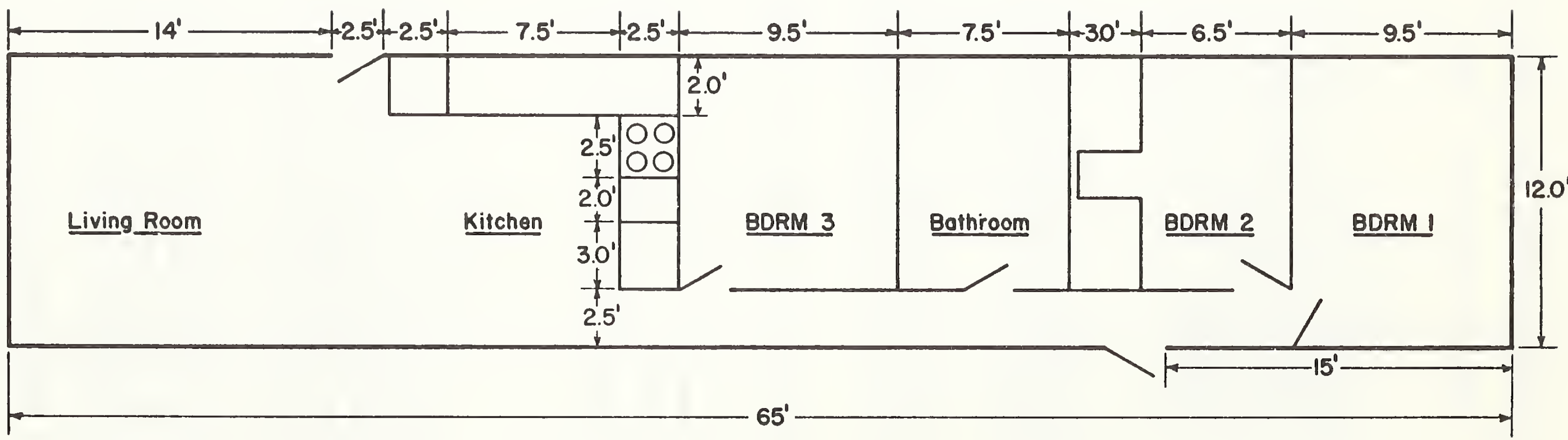



Figure 1. Floor Plan of the Mobile Home Test Unit

Phase 1 consisted of 13 experiments designed to examine the type of potential fire sources and incident heat flux resulting from cooking on a kitchen range.

Phase 2 consisted of 12 tests where specific emphasis was placed on evaluating the resistance of the underside of the cabinet directly above the range as a function of the clearance provided. The ANSI Standard for Mobile Homes, ANSI A119.1, 1974 edition, requirement for clearance above the kitchen range is 30 inches (76.2 cm), unless (a) the cabinet above the cooking top is protected with asbestos millboard at least 1/4 inch (0.64 cm) thick and covered with sheet metal of minimum No. 28 manufacturer's standard gage, or (b) a metal venting hood of No. 28 standard gage is installed with 1/4 inch (0.64 cm) air space between the hood and the cabinet bottom. If either of these design features is included, a 24-inch (61.0-cm) minimum clearance is permitted.

Phase 3 consisted of 16 tests from which an evaluation was made of the performance under fire conditions of the entire cabinet assembly directly above the range, along with the cabinet assemblies adjacent on the left and right, the ceiling above these 3 assemblies, and the wall directly behind the range. The performance under exposure to the test fires was evaluated as a function of the material of the cabinet doors, the presence of a metal kitchen range hood, the installation of a thin sheet of asbestos millboard on the underside of the cabinet directly above the range, and the type of wall paneling behind the range.

In this study, no tests were conducted to evaluate the effects of (a) the type of energy source utilized by the range (gas vs electric vs oil), (b) the time required for preheating, (c) malfunctions of the range, or (d) temperature, humidity or other environmental conditions, since the ignition of the cooking oil was the dominating factor.

When the effects of a range hood were investigated, a No. 26 manufacturer's standard gage (corresponding to 0.017 in and 0.043 cm) steel overhead range hood which was of the non-exhausting type and designed to provide a 5-inch eyebrow (5-inch overhang) beyond the vertical surface of the cabinet face was used (see fig. 2). This type of hood is typically used for collecting vapors from cooking oil and grease over kitchen ranges in mobile homes. The installation of 1/4-in (0.635-cm) thick asbestos millboard on the underside of the cabinet, recommended in ANSI 119.1, 1974 edition, paragraph 6.3.4.1, was included among the 16 tests of Phase 3 to evaluate its effect on performance of the cabinet system.

In Phase 2, temperatures were monitored in 12 locations on the surfaces of the cabinets and wall above the range (see fig. 3). In Phase 3, the number of locations was increased to 25. They were again located on the surfaces of the cabinets and wall above the range and monitored not only temperatures at surfaces near the ignition source but also on the ceiling above the range, on the refrigerator in the kitchen, and on the far left wall of the kitchen (see fig. 4). In addition, air temperatures were measured in several locations inside the center cabinet itself and inside adjacent cabinets. In all cases, temperatures were monitored using glass fiber insulated 24-gage, Chromel and Alumel thermocouples. In Phase 2, the thermocouples were connected to a multiple point strip chart recorder. In Phase 3, the thermocouples were connected to a high speed multiple channel data acquisition system.

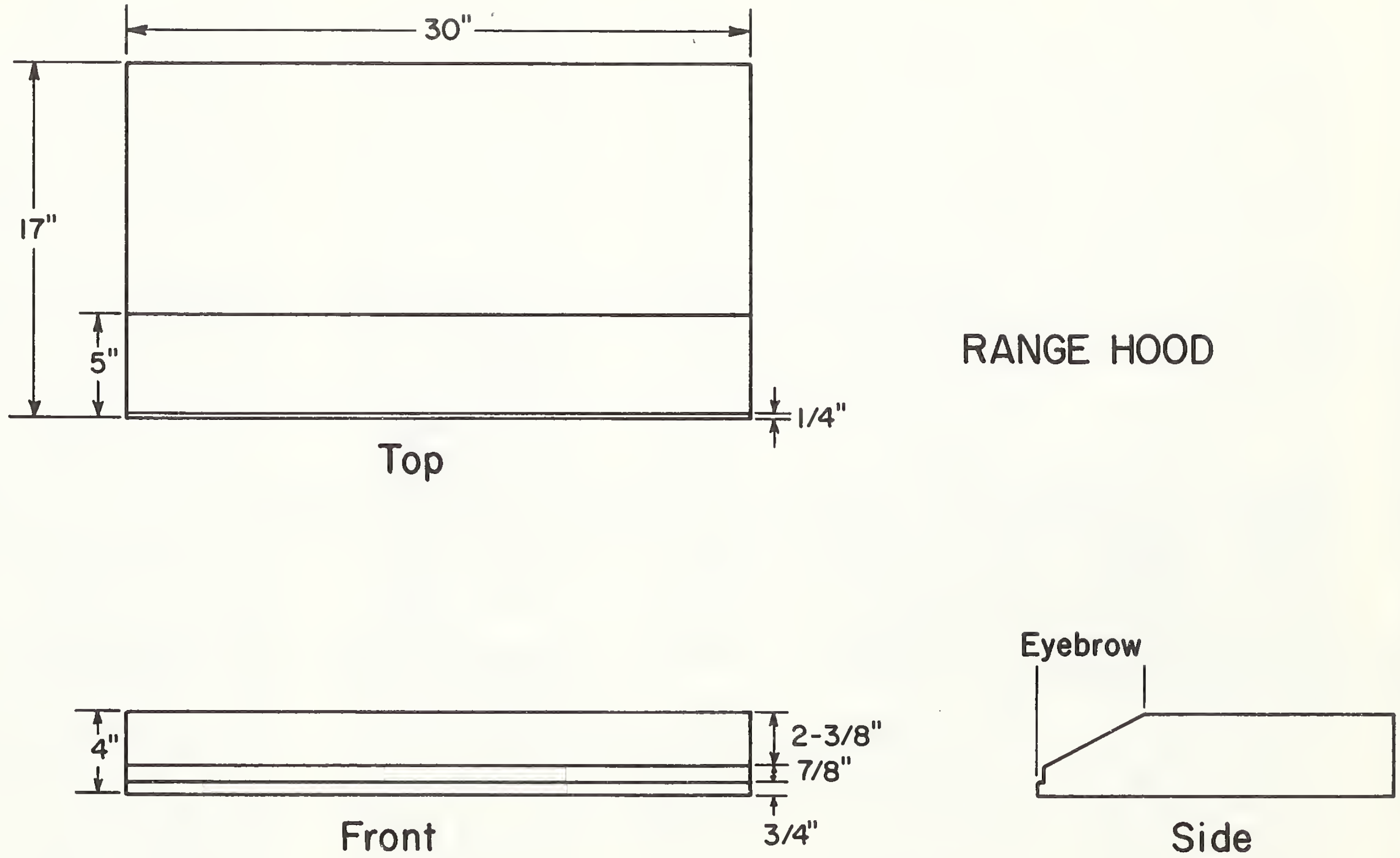
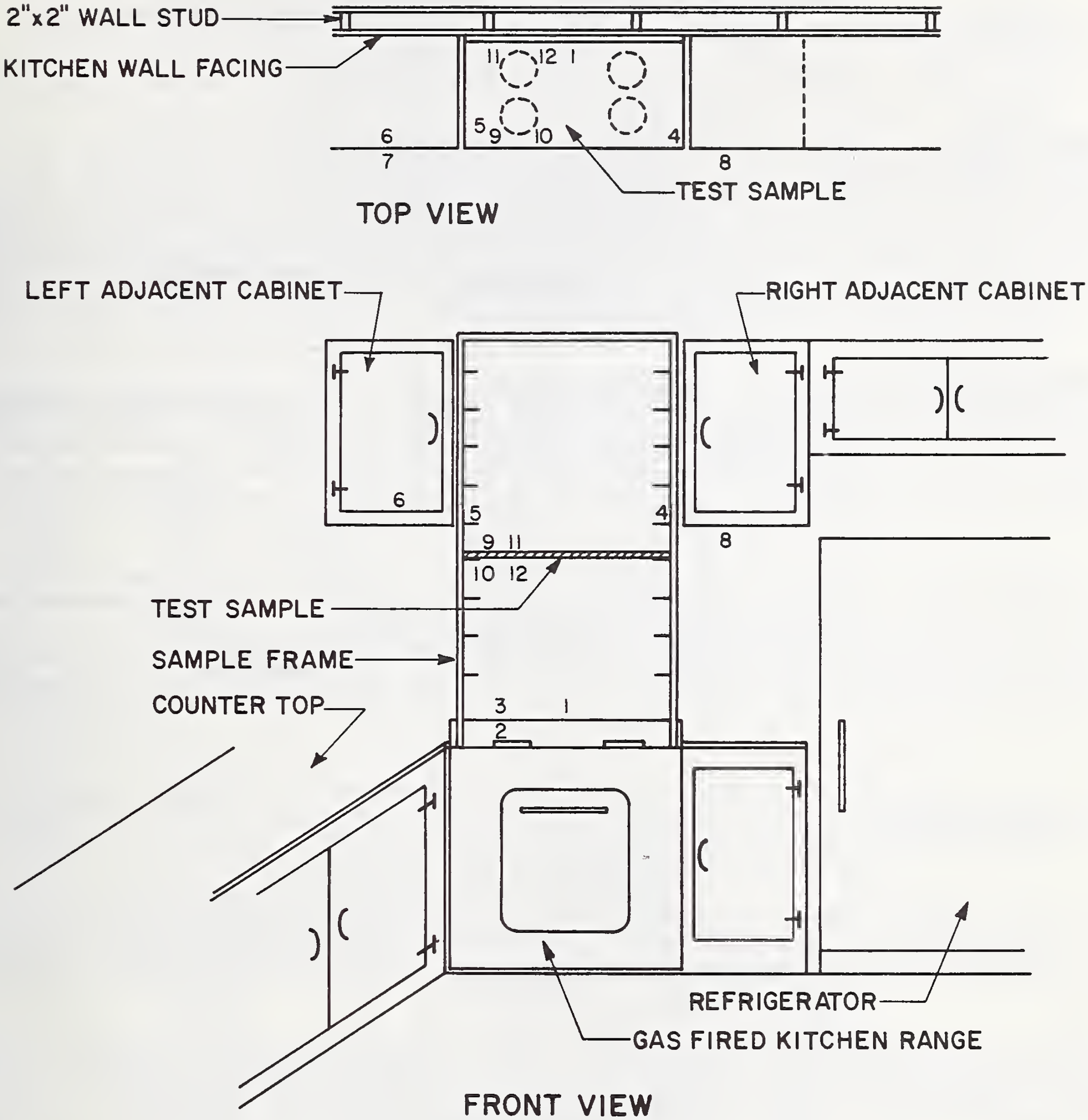



Figure 2. Kitchen Range Hood




THERMOCOUPLE LOCATIONS

1 - Surface of Back Wall
2 - Submerged in Oil
3 - Directly Above Flame from Oil
4 - Exterior Surface of Right Cabinet
5 - Exterior Surface of Left Cabinet
6 - Interior Airspace of Left Cabinet
7 - Underside Surface of Left Cabinet
8 - Underside Surface of Right Cabinet
9-12 - Surface of Sample — Exposed & Unexposed Sides

Figure 3. Test Set-Up for Phase 2: Apparatus and Instrumentation Locations

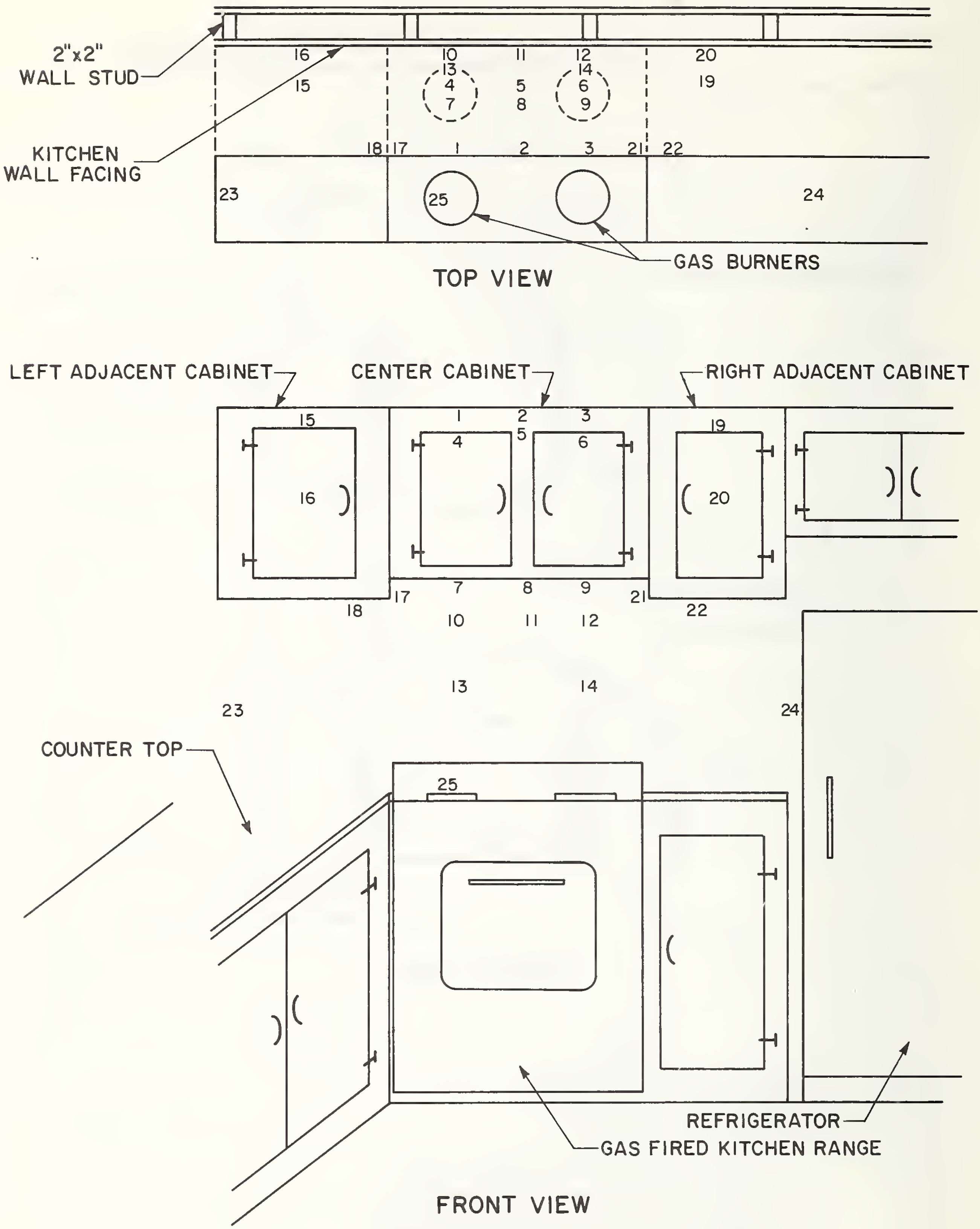



Figure 4. Test Set-Up for Phase 3: Apparatus and Instrumentation Locations

## 2. EXPERIMENTAL DESIGN

### 2.1. Materials and Apparatus

A pan containing preheated cooking oil was ignited by a match after the temperature of the oil reached approximately 380 °C. The oil then served as the ignition source, providing a fairly reproducible type of open flaming ignition commonly resulting from kitchen activities.

The materials selected as representative of kitchen cabinet construction were (a) 5/32-inch printed lauan plywood with an ASTM E-84 tunnel test flame spread rating corresponding to Class C (76-200) [2] and, (b) 1/2-inch printed particle board. Cabinet doors installed in the test units were printed lauan plywood and printed particle board of similar thickness to those above, and hollow core molded polystyrene. All materials tested were selected from actual mobile homes or were obtained directly from mobile home and kitchen cabinet manufacturing plants.

For Phases 1 and 2, the section of cabinet directly over the range was removed without alteration of the overhead cabinets adjacent to it in order to provide space for a welded steel framework which was installed on top of the gas-fueled kitchen range (see fig. 3). The frame was designed to hold cabinet material samples above the range at heights varying between 9 and 33 inches (22.9 and 83.8 cm).

For Phase 3, the framework was removed and cabinets were re-installed above the range as in the original construction (see fig. 4). The system of cabinets consisted of a center cabinet directly above the kitchen range, and cabinets on the left and right adjacent to the center cabinet. There were other cabinets in the kitchen area but only the three described above were considered in the test procedure. Specifications for the three test cabinets are as follows:

Left Adjacent Cabinet: Dimensions were 13.5 in wide x 28 in high x 12 in deep (34.3 cm x 71.7 cm x 30.5 cm). The entire unit, including the door, was constructed of 5/32-inch printed lauan plywood stapled to 3/4 in x 1-1/4 in (1.9 cm x 3.2 cm) pine framing. The door had a hollow core.

Right Adjacent Cabinet: Dimensions were 18.5 in wide x 28 in high x 12 in deep (47.0 cm x 71.1 cm x 30.5 cm). The cabinet door also had a hollow core. This cabinet was constructed in the same manner and using the same material as the left adjacent cabinet.

Center Cabinet: Different cabinet units were installed directly above the range to accommodate the different types of doors tested. However, the overall enclosure dimensions were always 30 in wide x 24 in high x 12 in deep (76.2 cm x 70.0 cm x 30.5 cm), and there were always 2 doors. Exact specifications for these units are given in the appendix.

During the process of renovating the mobile home between Phases 2 and 3, the refrigerator was removed, as well as the floor cabinet between the kitchen range and the refrigerator. They were replaced by simulated units constructed of 5/8-inch Type-X gypsum board on a frame of 2-inch x 2-inch pine. The dimensions of the cabinet (constructed of 5/8-inch gypsum) were 21 in wide x 37 in high by 26 in deep (53.3 cm x 94.0 cm x 66.0 cm). The dimensions of the refrigerator were 29 in wide x 60 in high x 26 in deep (73.7 cm x 152.4 cm x 66.0 cm). In addition, a piece of manufacturers standard 26-gage metal was placed on the refrigerator side to closely simulate the thermal characteristics of an actual refrigerator.

## 2.2. Experimental Details — Phase 1

Phase 1 of the test series was conducted to determine the type of ignition that would be used in testing the cabinets under a fire condition.

The equipment included an asbestos sample 24.5 in x 27 in (62.2 cm x 68.9 cm) with 4 holes provided for installation of heat flux transducers to measure radiant and convective heat directly above the range burners (see fig. 5).

Initially, two calibrated, commercial heat flux transducers of the water-cooled Gardon type, were located in various combinations in the four holes in the asbestos sample. These were used to determine the total heat flux incident on the bottom surface of the kitchen cabinet directly above the range resulting from the maximum output of any combination of two burners.

After determining the combination of two burners which provided the maximum output of the range, the total incident heat flux was recorded as a function of distance above these two burners. This was accomplished by adjusting the height of the asbestos sample above the range from a minimum of 9 inches (22.9 cm) to a maximum of 33 inches (83.3 cm).

The procedure was then repeated utilizing preheated 100% vegetable oil in a 9-in (22.9-cm) diameter cast iron cooking pan. The pan was filled to a depth of 0.5 in (1.27 cm) which provided a surface area of 63.6 $in^2$ (410 $cm^2$), and a volume of 31.8 $in^3$ (521 $cm^3$) for ignition of the oil.

In the test involving the preheated pan of vegetable oil, the range of distances was limited from 21 in to 30 in (53.3 cm - 76.2 cm), a more practical range when considering overhead cabinet construction. Total incident heat flux was then recorded as a function of distance above the burning oil by a heat flux transducer placed directly above the center of the burning pan as was done when measuring the heat flux from the kitchen range burners.

## 2.3. Experimental Details — Phase 2

Utilizing the open flame ignition source (preheated vegetable oil, in a 9-in diameter pan) pretested in Phase 1, a series of 12 tests were conducted to evaluate the performance of a typical cabinet material at varying heights from 22.5 in to 31 in (57.2 cm to 78.7 cm) above the ignition source on the range.

The 5/32-inch lauan plywood samples were precut to measure 27 in x 13 in (68.9 cm x 33.0 cm) and fit into the frame assembly. Natural ventilation was provided by partially opening windows in the test unit, but actual air movement was slight, and therefore disregarded. When the range hood was included, it was placed in the apparatus and the sample was attached to the top side of the hood.

In each test, cabinet doors were installed on the adjacent cabinets. Both printed particle board and molded polystyrene cabinet doors were tested.

Temperature was monitored as a function of time at 12 locations, including the exposed and unexposed sides of the sample, the adjacent cabinet surfaces and walls, and cabinet door (fig. 3). The temperatures were recorded on a 24-point chart recorder. Observations were made and recorded for changes in sample performance and progress of the fire.

The duration of the fire was limited in order to prevent excessive damage to the apparatus and the kitchen area. The fire was extinguished when it appeared to the test observers that extensive involvement would result from continuation.

Figure 5. Test Apparatus for Measuring Incident Heat Flux

### 2.4. Experimental Details — Phase 3

Utilizing the open flame ignition source (preheated vegetable oil), a series of 16 tests was conducted to evaluate the performance of the system of 3 cabinet assemblies located above the range using doors constructed of a variety of materials on the center cabinet (see fig. 4). The range hood, when used, was screwed onto the underside of the center cabinet. In addition, a 12 in x 30 in x 1/4 in (30.5 cm x 76.2 cm x 0.64 cm) piece of asbestos millboard was installed between the hood and the underside of the center cabinet in six of the tests. Hollow core lauan plywood doors of identical construction to those described in section 2.2, were used on the adjacent cabinets for all 16 tests.

A 10-inch (25.4-cm) diameter pan was substituted for the 9-inch pan for Phase 3. It was filled to 0.5 in (1.27 cm) which provided a surface area of 78.5 $in^2$ (506.5 $cm^2$) and a volume of 39.25 $in^3$ (643 $cm^3$) for ignition of the preheated 100% vegetable oil. In one case (Test 12), the depth of the vegetable oil was reduced to 0.25 in (0.64 cm).

Temperature was monitored as a function of time at 25 locations, fed through a high speed multi-channel data acquisition system and recorded on a magnetic tape, which was then processed by computer. Thermocouple locations included the air space inside of the center cabinet; the air space inside and surface of both adjacent cabinets; and the surface of the back wall, the ceiling, the far left wall, and the refrigerator (see fig. 4). Observations were recorded concerning the performance of the cabinet material and the progress of the fire. The construction of the exposed back wall behind the range was varied among the tests to include (a) 5/32-inch lauan plywood (typical), (b) 5/8-inch Type-X gypsum board, and (c) 5/32-inch lauan plywood over gypsum board.

The duration of the fire was limited, as in Phase 2, to prevent complete destruction of the kitchen area so that subsequent tests could be conducted without extensive rebuilding.

## 3. TEST RESULTS

### 3.1. Data from Phase 1 — Incident Heat Flux Measurements

At a constant height of 9 inches (22.9 cm) above the range top, the maximum incident heat flux from the range was determined to be 0.84 $\pm$ 0.02 Btu/ft$^2$ s (0.96 $\pm$ .02 W/cm$^2$). This was obtained when the back left gas burner was adjusted to maximum output. The variation was a result of some contribution from one of the other burners, since this part of the test was conducted utilizing combinations of two burners at one time.

The combination which provided the maximum total incident heat flux of 0.8 Btu/ft$^2$ s (0.96 W/cm$^2$) was the two back burners in a state of maximum output. When this source was held constant and the height of the sample was varied, the total incident heat flux ranged from 0.85 Btu/ft$^2$ s (0.97 W/cm$^2$) at 9 inches (22.9 cm) to 0.11 Btu/ft$^2$ s (0.12 W/cm$^2$) at 30 inches (76.2 cm). Figure 6 shows these results.

Figure 7 shows the results of the second part of Phase 1, when the pan of vegetable oil was utilized. The total incident heat flux ranged from 3.18 Btu/ft$^2$ s (3.61 W/cm$^2$) at a distance of 21 inches (53.34 cm) above the flame source to 1.5 Btu/ft$^2$ s (1.72 W/cm$^2$) at 30 inches (76.2 cm). From this it was assumed that while two burners alone may not provide sufficient heat to readily ignite the material samples, there would be sufficient total incident heat flux output from a kitchen fire incident involving cooking oil to ignite materials utilized in the immediate area of the range, specifically cabinets. It was also determined that a cooking oil fire over either back burner caused a greater buildup of heat than a fire over either front burner since the rear burners are more enclosed (by the back wall partition and overhead cabinets) than the front burners. Using this information, Phase 2 of the test series was initiated.

### 3.2. Data from Phase 2 — Cabinet Material Tests

Table 1 illustrates the recorded test data collected for each test; the data is grouped into 3 areas for simplification:

1) the test conditions,
2) key points in the progression of each test as a function of time, and
3) maximum temperatures reached at critical locations.

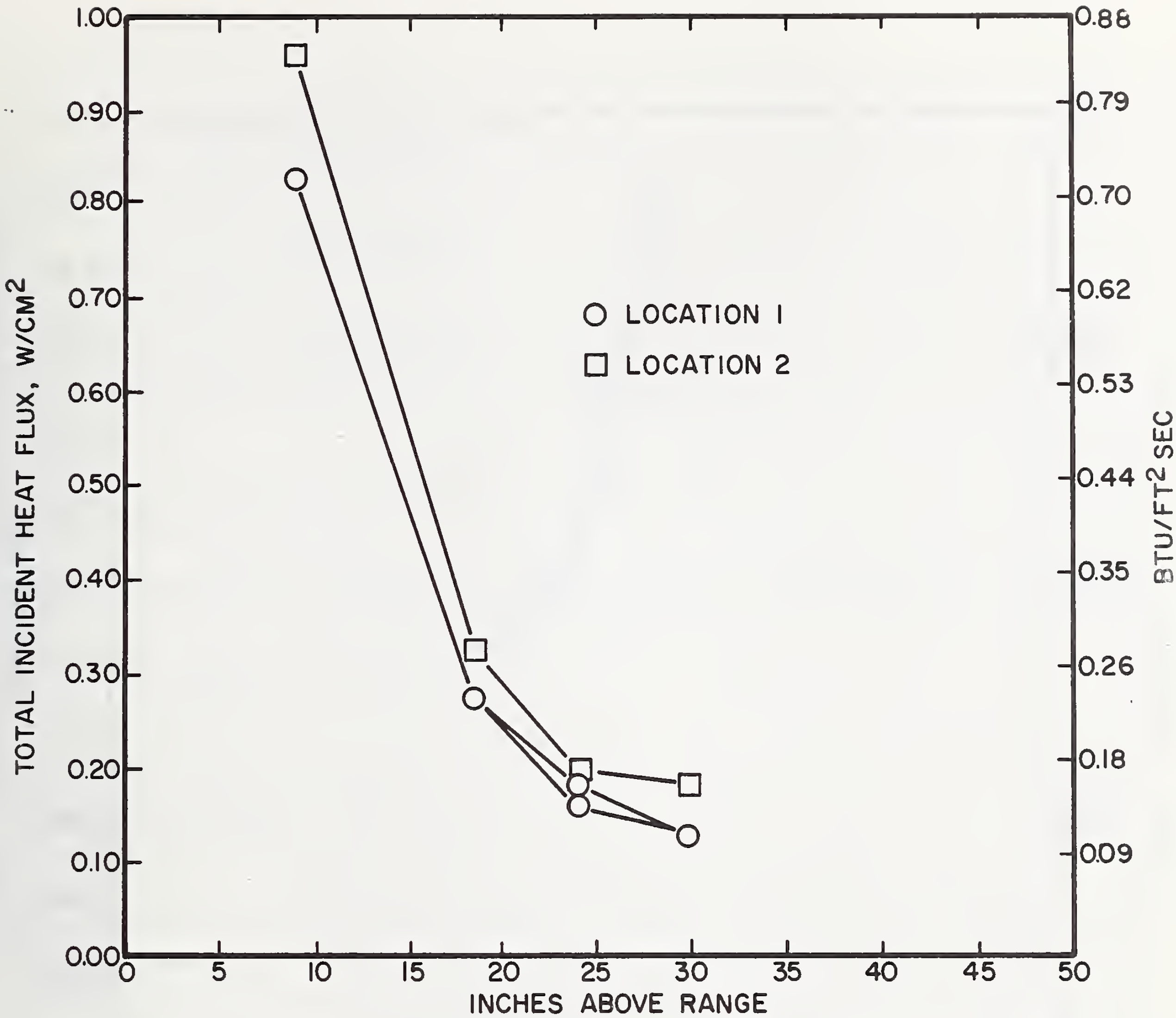
### 3.3. Data from Phase 3 — Cabinet Assembly Tests

Table 2 illustrates the recorded test data collected for each test. Again, the data is organized into 3 groups as above.

## 4. DISCUSSION

### 4.1. Phase 2 — Cabinet Material Tests

The series of tests conducted in Phase 2 provide experimental data supporting an initial assumption that the distance above the burning oil directly affects the time at which ignition of combustible cabinet material occurs.



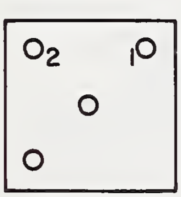




Figure 6. Incident Heat Flux from Maximum Output of Two Back Burners of an LP-Gas Fired Kitchen Range

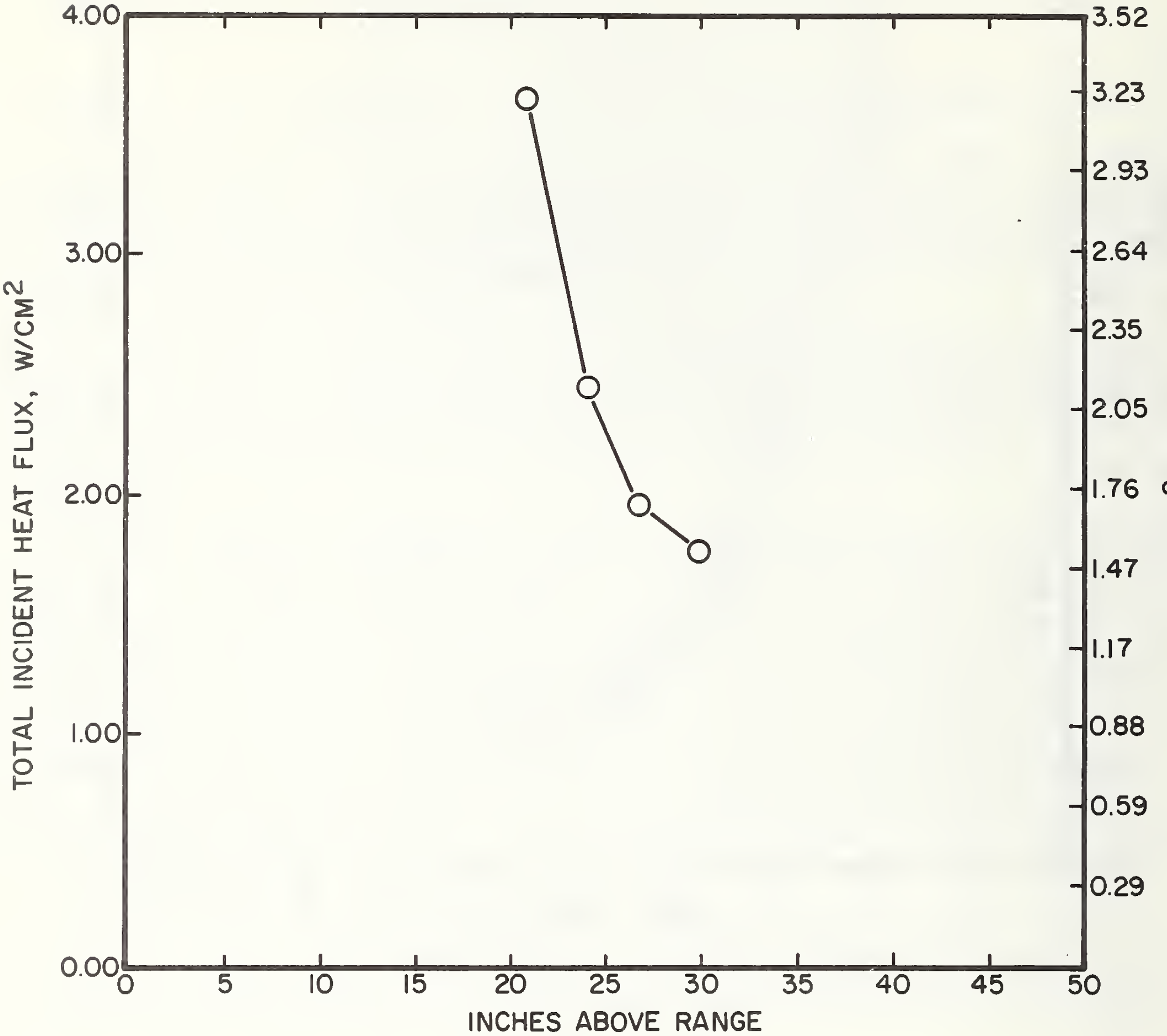



Figure 7. Incident Heat Flux from a Pan of Burning Vegetable Oil Placed on a Kitchen Range

Table 1. Kitchen Cabinet Tests, Phase 2 — Cabinet Material Tests

| | Test Conditions | | | | | Test Observations (min:s) | | | | | | | Max. Temp at Critical Locations (°C) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ignition Source Location | Sample Type: A = Printed Lauan Plywood B = Molded Polystyrene | Ht. of Sample Above Range Top (Inches) | Range Hood: I=Installed/N=Not Installed | Adjacent Cabinet Door Material: R/L Indicates Right/Left C = Printed Particle Board D = Molded Polystyrene | Discoloration | Flame Impingement on Hood/Sample | Ignition of Sample | Ignition of Lt. Adjacent Cabinet Assembly | Ignition of Rt. Adjacent Cabinet Assembly | Flame Impingement on Ceiling | Termination of Test | Exposed Side of Sample | Unexposed Side of Sample | Wall Behind Range | Cabinet Exposure - Lt. Adjacent Cabinet Assembly | Cabinet Exposure - Rt. Adjacent Cabinet Assembly | Cabinet Exposure - Inside of Lt. Adjacent Cabinet Assembly |
| Test 1 | Front Left | A | 30 | N | L-C R-D | 3:35 | 2:40 | – | – | – | – | 7:02 | 240 | 155 | 90 | 80 | 60 | 50 |
| Test 2 | Rear Left | A | 30 | N | L-C R-D | 1:40 | 1:40 | 2:10 | – | – | – | 2:30 | 790 | 690 | 430 | 430 | 115 | 60 |
| Test 3 | Rear Left | A | 22.5 | N | L-C R-D | :55 | :55 | 1:30 | – | – | – | 1:45 | 620 | 160 | 560 | 200 | 200 | 60 |
| Test 4 | Rear Left | A | 22.5 | I | L-C R-D | – | 1:20 | 3:45 | 3:15 | – | – | 4:00 | 730 | 200 | 670 | 360 | 120 | 130 |
| Test 5 | Rear Right | A | 22.5 | I | L-C R-D | – | 1:40 | 4:45 | – | – | 5:00 | 5:20 | 710 | 510 | 590 | 150 | 200 | 80 |
| Test 6 | Rear Right | A | 22.5 | N | L-C R-D | :50 | :50 | 1:15 | – | 4:00 | – | 5:00 | 525 | 180 | 265 | 165 | 215 | 50 |
| Test 7 | Rear Right | A | 25 | N | L-C R-D | 1:25 | 1:25 | 2:10 | – | 2:05 | – | 3:15 | 670 | 710 | 200 | 170 | 370 | 70 |
| Test 8 | Rear Right | A | 30 | N | L-C R-D | – | – | – | – | – | – | 5:00 | 215 | 125 | 120 | 100 | 130 | 65 |
| Test 9 | Rear Right | A | 30 | N | L-C R-D | 1:40 | 1:40 | 3:10 | – | 2:45 | – | 3:32 | 650 | 275 | 175 | 125 | 280 | 70 |
| Test 10 | Rear Right | A | 31 | I | L-C R-D | – | – | – | – | 3:45 | 7:45 | 8:00 | 420 | 140 | 195 | 160 | 230 | 85 |
| Test 11 | Rear Right | A | 26 | I | L-C R-D | – | :30 | – | 1:55 | – | – | 2:40 | 670 | 130 | 320 | 560 | 100 | 155 |
| Test 12 | Rear Right | B | 26 | I | L-C R-D | – | 1:00 | 3:00 | – | – | – | 3:30 | 615 | 600 | 370 | 100 | 105 | 70 |

Table 2. Kitchen Cabinet Tests, Phase 3 — Cabinet Assembly Tests

| | Test Conditions | | | | | | Test Observations (min:s) | | | | | | | | | | | | | Max. Temp. at Critical Locations (°C) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ignition Source Location | Relative Humidity - % Inside/Outside | Cabinet Surface Material A = Printed Lauan Plywood B = Molded Polystyrene C = Printed Particle Board | Ht. of Test Cabinet Above Range Top (Inches) | Range Hood: I = Installed N = Not Installed | Asbestos Millboard I = Installed N = Not Installed | Flame Impingement on Center Hood/Cabinet | Ignition of Center Cabinet | Flame Impingement on Center Cabinet Doors | Ignition of Center Cabinet Doors | Flame Impingement on Lt. Adjacent Cabinet | Ignition of Lt. Adjacent Cabinet | Flame Impingement on Rt. Adjacent Cabinet | Ignition of Rt. Adjacent Cabinet | Flame Impingement on Back Wall / Ignition of Back Wall | Flame Impingement on Ceiling | Ignition of Ceiling | Lateral Impingement on Refrigerator | Termination of Test | Ceiling Above Range | Ceiling Inside Cabinet Assembly | Exposed Side of Cabinet Bottom | Back Wall | Exposed Bottom Side of Lt. Adjacent Cabinet Assembly | Exposed Bottom Side of Rt. Adjacent Cabinet Assembly | Refrigerator |
| Test 1 | Front Left | 38/41 | C | 24.5 | I | I | 1:30 | 2:50 | 1:50 | 3:50 | 2:45 | 3:00 | 3:00 | - | Class C<br>2:00 3:10 | 3:20 | - | 4:00 | 6:00 | 226 | 57 | 79 | 674 | 534 | 344 | 96 |
| Test 2 | Front Left | 32/34 | C | 24.5 | I | N | 1:15 | - | 1:45 | - | 2:30 | - | - | - | Class A<br>- - | - | - | - | 5:45 | 193 | 50 | 178 | 349 | 298 | 218 | 35 |
| Test 3 | Front Left | 30/34 | C | 24.5 | I | N | :45 | 3:00 | 2:10 | 3:00 | 2:20 | 3:20 | - | - | Class A<br>2:45 3:00 | 2:35 | - | - | 4:15 | 245 | 72 | 348 | 579 | 487 | 315 | 46 |
| Test 4 | Front Left | 36/34 | C | 24.5 | N | N | 2:30 | 2:50 | 2:30 | 2:50 | 2:30 | 2:55 | - | - | Class A<br>- - | 3:15 | 3:50 | - | 4:05 | 358 | 85 | 430 | 268 | 374 | 219 | 38 |
| Test 5 | Front Left | 32/41 | A | 24.5 | I | I | 1:15 | 2:50 | 2:30 | 3:00 | 2:40 | 3:10 | 3:20 | 3:30 | Class C<br>2:50 3:05 | - | - | - | 3:40 | 328 | 35 | 72 | 643 | 500 | 396 | 53 |
| Test 6 | Front Left | 30/36 | A | 24.5 | I | I | 1:30 | 3:55 | 3:25 | 3:55 | 3:30 | 3:55 | - | - | Class A<br>3:40 - | 4:40 | - | - | 5:10 | 231 | 61 | 111 | 634 | 613 | 284 | 44 |
| Test 7 | Front Right | 34/33 | A | 24.5 | N | N | 1:00 | 1:20 | 1:15 | 1:20 | 1:50 | - | 1:20 | 1:25 | Class A<br>1:45 - | 1:35 | 1:45 | - | 2:10 | 523 | 149 | 609 | 570 | 582 | 554 | 90 |
| Test 9 | Front Left | 50/65 | A | 24.5 | I | I | 1:05 | 2:20 | 2:05 | 2:50 | 2:15 | 2:50 | - | - | Class A<br>- - | 2:55 | - | - | 3:10 | 250 | 36 | 50 | 359 | 268 | 192 | 48 |
| Test 10 | Front Left | 46/62 | A | 24.5 | I | N | 1:45 | - | 1:50 | 2:25 | 1:55 | 3:00 | - | - | Class A<br>4:00 - | - | - | - | 6:00 | 163 | 51 | 197 | 344 | 564 | 190 | 49 |
| Test 11 | Front Left | 44/62 | A | 24.5 | N | N | 1:25 | 2:25 | 1:55 | 2:00 | 2:05 | 3:00 | - | - | Class A<br>- - | 2:20 | 3:05 | - | 3:20 | 378 | 54 | 449 | 233 | 462 | 254 | 53 |
| Test 12 | Rear Left | 44/62 | A | 24.5 | N | N | :20 | :40 | :35 | :45 | :45 | :55 | 1:00 | 1:10 | Class A<br>:40 - | - | - | - | 1:50 | 317 | 75 | 761 | 585 | 785 | 801 | 63 |
| Test 8 | Front Left | 42/44 | B | 24 | N | N | 2:30 | 3:30 | 2:35 | 3:00 | 2:40 | 3:30 | 2:50 | 4:15 | Class C on A<br>3:10 3:55 | 2:50 | 3:40 | - | 4:30 | 723 | 620 | 692 | 589 | 627 | 475 | 132 |
| Test 13 | Front Left | 54/68 | B/C | 24 | I | I | 1:10 | - | 2:00 | - | 2:55 | 4:50 | - | - | Class A<br>3:05 - | - | - | - | 5:40 | 222 | 92 | 64 | 362 | 252 | 220 | 62 |
| Test 14 | Front Left | 44/50 | B/C | 24 | I | N | 1:25 | - | 1:45 | 3:30 | 2:45 | 3:10 | - | - | Class A<br>- - | - | - | - | 6:00 | 219 | 115 | 194 | 384 | 352 | 217 | 61 |
| Test 15 | Front Left | 38/26 | C | 24 | I | I | :55 | 1:05 | 1:00 | 1:55 | 1:00 | 1:40 | - | - | Class C<br>- - | - | - | - | 6:00 | 217 | 58 | 74 | 343 | 660 | 189 | 79 |
| Test 16 | Rear Left | 38/25 | C | 24 | I | I | 1:00 | 1:25 | 1:10 | 1:45 | 1:15 | 1:30 | 1:05 | 1:15 | Class C<br>1:15 1:25 | 1:40 | 2:10 | 1:35 | 2:50 | 781 | 327 | 156 | 925 | 972 | 630 | 177 |

Further, the tests indicate that a cooking oil fire of the type used for this test series may result in ignition of the surrounding combustible cabinets or rear wall in as little as 1 minute-15 seconds (Test 6).

In analyzing the results of Phase 2, the data from Test 8 was not included since that test fire did not develop to a level comparable with the other 11 tests.

Under the conditions where either rear burner was used and a hood was not installed above the range, all of the samples ignited. The shortest time (1 minute-15 seconds) to sustained burning of a sample occurred at a distance of 22.5 in (57.15 cm). The longest time (3 minutes-10 seconds) occurred at a sample height of 30 in (76.2 cm). The total time range was 1 minute-55 seconds. Both of these represent extremes in construction practicality, but even at a more typical height of 25 in (63.5 cm), sustained ignition occurred at 2 minutes-10 seconds (Test 7).

In the series of tests where a manufacturers standard No. 26 gage steel hood was installed, the performance of the material samples was notably different. For example, in Test 5, at a distance of 22.5 in (57.15 cm) sustained ignition did not occur until 4 minutes-45 seconds, which is greater by more than a factor of 2, than the time associated with sustained ignition of the sample at 30 in (76.2 cm) without the hood in Test 2. Furthermore, at heights of 26 in (66.04 cm) and 31 in (78.74 cm), there was no ignition of the sample above the hood, although ignition of the side cabinet and back wall occurred.

Test data indicate that there is a fire potential due to exposure of adjacent cabinets. In a number of the tests where the height of the sample material above the range was 25 in (63.5 cm) or greater and the hood was not installed, a cabinet adjacent to the sample ignited within 30 seconds prior to the sample (Tests 7, 9). In 2 out of 3 of the tests where the hood was installed, an adjacent cabinet ignited while the overhead sample did not (Tests 10, 11). It was also discovered that the installation of a hood resulted in an increased problem with the back wall due to re-radiation and exposure of the wall to high temperature turbulent convection occurring where the hood and back wall meet.

It should be noted that these general conclusions are directed specifically at the performance of a Class C (ASTM E-84 Tunnel Test) lauan plywood paneling which was found to be the typical construction material used for cabinet undersides and wall construction in the three test units.

One test was conducted in Phase 2 (Test 12) where a sample of molded polystyrene was placed at 26 in (66.04 cm) and a hood was installed. While the results are limited, the sample deformed and ignited in 3 minutes while in a similar test of Class C lauan plywood (Test 11), there was no ignition of the sample. This warranted further investigation in Phase 3 due to a potential trend in the materials industry to provide molded polystyrene cabinet construction [3].

There was some difficulty in reproducing the ignition source. Preheating times varied due to the buildup of residue in the pan which could not be removed after every test. And, even though ambient conditions were not considered a test variable, it is suspected that ambient temperature and humidity also may have slightly affected the time it took to reach ignition of the oil. The excessively low temperatures produced in Test 8 were attributed to these problems. As was mentioned previously, Test 8 was not included in the analysis.

Further, the testing was limited to the immediate area of the range. Sufficient time was provided for both horizontal and lateral propagation of the fire, but the severity was limited by the test group in order to provide a

reasonable level of reproducibility. It was anticipated by the test personnel that continuation of any of the tests (excluding Test 8) would have resulted in involvement of the entire kitchen area which would have destroyed the test apparatus.

### 4.2. Phase 3 — Cabinet Assembly Tests

The series of 16 tests in Phase 3 was conducted to evaluate the performance of kitchen cabinet assemblies, including a variety of design modifications, under conditions resulting from the ignition of a pan of vegetable oil.

In every test where the assembly did not include a metal range hood and asbestos millboard insulation, the surface of the cabinet doors, regardless of the door material, ignited within the range of 20 to 25 seconds after flame impingement on the bottom surface of the cabinet (Tests 4, 7, 8, 11, 12). In addition, the maximum ceiling temperatures produced were significantly higher for those assemblies which did not include a metal range hood.

When a metal range hood was included in the assembly the time period from when the ignition source first impinged on the exposed side of the assembly to ignition of the cabinet assembly itself was increased significantly (see figs. 8 and 9). In most cases the time period was increased by a factor of 4 or 5. (Comparison of tests 6 and 7 provide an illustration. In Test 7, the time period in question was 20 seconds; in Test 6, with a similar cabinet assembly, but with a metal hood installed, the time was increased to 2 min-25 s).

There was a significant decrease in the maximum temperature recorded on the exposed side of the cabinet bottom when, along with a hood, 1/4-inch asbestos millboard was utilized as an insulator. Comparison of tests where the asbestos millboard and range hood were installed against tests of similar cabinet materials when neither the hood nor the millboard were used, show that the installation of the asbestos millboard and the hood decrease temperatures on the exposed side of the cabinet by at least a factor of 2 (Tests 4 and 16, 11 and 6, 8 and 13).

In Phase 2, it was recognized that the exposed wall behind the range in the kitchen may pose a serious potential for flame propagation beyond the immediate area of the range. Therefore, in Phase 3, the construction of the back wall was altered to include 5/32-inch lauan plywood for some of the tests, and 5/8-inch gypsum board for others (5/8-inch gypsum was used due to availability; it is the authors' opinion that 5/16-inch gypsum board would have been adequate).

In Tests 1, 5, 8 and 16, analysis of the test data supported the conclusion from Phase 2 that the installation of a metal range hood reduces the time to sustained ignition of a back wall constructed from 5/32-inch lauan plywood.

In Tests 1, 5, and 16, the use of 5/32-inch lauan plywood with an ASTM E-84 flame spread rating of Class C (76-200) resulted in burn-through to the adjacent bedroom (see fig. 10) exposing the electrical wiring in the wall partition as well as providing the flames with a vertical path into the ceiling cavity. The Class C material also allowed lateral propagation, including flame impingement on the refrigerator. Observations from Test 16 indicate that impingement on the refrigerator occurred at 1 min-35 s. This test was, however, somewhat more dramatic than Tests 1 and 5, and it appears as though the low relative humidity in Test 16 may have contributed to this. The time recorded for Test 1 was 4 minutes, which was under more normal environmental conditions.


Figure 8. Illustrates the Extent of Involvement of a Cabinet Assembly Without a Metal Range Hood (Time: 2 min-20 s)

Figure 9. Illustrates the Extent of Involvement of a Cabinet With a Metal Range Hood (Time: 2 min-20 s)


Figure 10. Illustrates Burn-Through of the Back Wall in Test 16; the Wall was Constructed of 5/32-inch Printed Lauan Plywood

In Test 8, the 5/32-inch lauan plywood was installed over a subsurface of 5/8-inch gypsum board. Test observers noted that while penetration (burn-through) of the partition was prevented, the lateral propagation across the back wall was only slightly impaired.

In the tests which utilized a 5/8-inch gypsum board partition, there was no evidence of failure of the partition or lateral propagation beyond the area of direct impingement of the ignition source.

While these tests were not designed specifically to evaluate the fire hazards associated with various types of cabinet door materials, the test data and observations did provide some interesting information.

In analyzing the data from those tests in which the assembly did not include a metal range hood or a 1/4-inch asbestos millboard insulator, the most severe temperatures reached at the ceiling occurred when the cabinet doors were constructed of molded polystyrene. However, in those tests which included the hood, and/or the asbestos millboard, there were no appreciable differences in temperatures associated with the type of material used for the cabinet doors.

In all three tests in which polystryene doors were tested, the door assemblies failed (see fig. 11), resulting in greater temperatures inside the cabinet and ignition of the countertops and the vinyl flooring due to direct exposure from the melting and burning cabinet door debris. However, as the doors melted and dripped away from the cabinet assemblies, ceiling temperatures were reduced. Greater quantities of smoke and irritants were noted by observers during the tests which included the molded polystyrene doors than during the other tests.

Figure 11. Illustrates the Performance of a Molded Polystyrene Cabinet Door (left) and a Printed Particle Board Cabinet Door (right) to a Test Fire. In this Test a Metal Range Hood was Installed.

In the tests in which lauan plywood and/or particle board doors were tested, there was no failure of the door assemblies. While production of irritants and smoke was less, and maximum temperatures in the cabinets were lower, the ceiling temperatures were considerably greater than during the tests with polystyrene doors. It appears that when the polystyrene doors distorted and began to melt down, the temperatures at the ceiling were reduced due to a reduction of fuel near the ceiling. In those tests where lauan plywood or particle board doors were installed, ceiling temperatures continued to increase.

The tests were conducted under full-scale conditions in an actual mobile home. Therefore, environmental effects were controlled only to the point of maintaining the interior temperature at approximately 20 °C (68 °F). Relative humidity varied somewhat throughout the test series and therefore would be expected to have some minimal effect on the test data.

Finally, Test 15 was not included in the analysis due to failure of the ignition source to develop fully. This failure was attributed to difficulties in the preheating state of the test and, as with Test 8 of Phase 2, to environmental conditions (specifically high relative humidity).

## 5. SUMMARY

Based on the limited tests reported here, the following summary appears justified:

1. A pan of cooking oil which burns freely for as little as 40 seconds on a range in a mobile home kitchen represents a risk of fire and involvement of the cabinets and back wall in the kitchen area.

2. For the range of clearances studied (22.5 to 31 in (57.2 to 78.7 cm)), the height to the bottom surface of the cabinet directly above the range has a slight affect on the time it takes to reach sustained burning of the cabinet. Without a metal range hood, sustained burning of the Class C cabinet underside occurred within 3 minutes in the majority of tests a cooking oil fire.

3. Installation of a range hood of a design similar to that used in the test series provides significantly improved resistance to sustained burning of the underside of the cabinet directly above the range, significantly reduces the rate of temperature rise and maximum temperatures at the ceiling above the range, and increases the time to ignition of the vertical surfaces of the cabinet assembly, including doors and trim.

4. Installation of 1/4-inch asbestos millboard between the underside of the cabinet and the metal range hood provides a significant reduction in temperatures transmitted to the cabinet underside. However, due to direct exposure, this does not prevent ignition of the cabinet in all cases.

5. Cabinets adjacent to the cabinet directly above the kitchen range can be ignited from a cooking oil fire, but not as readily as the cabinet directly above.

6. The partition behind the kitchen range represents a critical area for lateral flame spread and for fire penetration into the adjacent room due to a cooking oil fire on a rear burner. The presence of a range hood tends to increase this potential for the typical Class C partition material.

7. With a range hood installed, the differences in performance of the 3 types of cabinet door materials were less pronounced than with a range hood not installed. However, in all of the tests with polystyrene cabinet doors, there was a structural collapse of the door.

## 6. RECOMMENDATIONS

Based on experimental test results, there are two principal design recommendations which may be employed to minimize fire hazards associated with kitchen range fires in mobile homes:

1. It is recommended that a sheet metal hood (minimum No. 26 manufacturer's standard gage) be provided above the range with a minimum clearance above the range top of 24 inches. This hood should include a 5-inch eyebrow (overhang) to prevent direct impingement of a flame on the front vertical surfaces of the cabinet doors (see figure 2 for details of the range hood design utilized in this test series). In those cases where the hood and overhead cabinet are recessed, the exposed sides of adjacent cabinets should be protected by an extension of the hood design. It is also recommended that a sheet of minimum 1/4-inch asbestos millboard (or equivalent) be provided between the metal range hood, and the underside of the cabinet above and the sides of the adjacent cabinets. The underside of the adjacent overhead cabinets should be constructed of materials having a maximum flame spread rating not greater than 50 when tested in accordance with the Standard Method of Test for Surface Burning Characteristics of Building Materials, ASTM E84-70 [2], and a rating of limited combustibility as defined in NFPA No. 220, Types of Building Construction, 1975 edition [4].

2. It is recommended that the material comprising the exposed partition behind the range be limited to a material having a flame spread rating of not greater than 50 (under ASTM E-84) and a rating of limited combustibility (under NFPA 220, 1975 ed.) to prevent fire penetration into adjoining areas. This material should be attached by mechanical means and extend at least 18 in (45.7 cm) beyond the edge of the range to cover the area of flame impingement.

The experimental test data indicate that the difference in performance of the three types of cabinet doors (5/32-inch printed lauan plywood, 1/2-inch printed particle board, and molded polystyrene) was not vitally significant in that, while specific burning characteristics did differ somewhat between the different types of doors, the overall fire severity was similar. However, from observations it was noted that the production of smoke was significantly higher in those tests utilizing molded polystyrene. Therefore, it is recommended that laboratory testing be conducted to provide data on smoke generation for the materials tested.

## 7. ACKNOWLEDGEMENTS

The tests reported here were conducted by the authors and the following members of the Center for Fire Research: Mr. J. R. Lawson, Mr. T. F. Maher and Mr. W. I. Stull. Their efforts are greatly appreciated.

The project was supported in part by funds provided by the Mobile Home Manufacturers Association, Chantilly, Va.

Appreciation is expressed to the Kitchen Cabinet Manufacturers Association for providing a number of the kitchen cabinet assemblies used in the testing.

## 8. REFERENCES

[1] Tyron, G. H., A Talk on Mobile Homes and Fire Safety, presented to the 101st Annual Convention of the Firemen's Association of the State of New York, MH/RB Document No. 73-8 (Sept. 1973).

[2] Standard Method of Test for Surface Burning Characteristics of Building Materials, ASTM E84-70, American Society for Testing and Materials, Philadelphia, Pennsylvania (1970).

[3] Hall, A., Plastics are Rolling into Low-Cost Housing via the Mobile Home Route, Modern Plastics, Vol. 49, No. 6, 58-61 (June 1972).

[4] Types of Building Construction, NFPA 220-1975, National Fire Protection Association, Boston, Massachusetts (1975).

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## APPENDIX - SPECIFICATIONS FOR THE CENTER CABINET ASSEMBLY USED IN PHASE 3

| TESTS | DIMENSIONS (WIDTH x HEIGHT x DEPTH) CABINET BODY | EACH DOOR | FALSE FRONT | TOTAL ASSEMBLY | |
|---|---|---|---|---|---|
| 1,2,3,4 | 30 x 24 x 12<br>76.2 x 61.0 x 30.5 | 13.5 x 22.5 x 0.5<br>34.3 x 57.2 x 1.3 | -<br>- | 30 x 24 x 12<br>76.2 x 61.0 x 30.5 | inches<br>centimeters |
| 5,6,7 | 30 x 14.5 x 12<br>76.2 x 36.8 x 30.5 | 14.5 x 10.5 x 1<br>36.8 x 26.7 x 2.5 | 30 x 9.5 x 5/32<br>76.2 x 24.1 x 0.4 | 30 x 24 x 12<br>76.2 x 61.0 x 30.5 | inches<br>centimeters |
| 8 | 30 x 24 x 12<br>76.2 x 61.0 x 30.5 | 13 x 21 x 1<br>33.0 x 53.3 x 2.5 | -<br>- | 30 x 24 x 12<br>76.2 x 61.0 x 30.5 | inches<br>centimeters |
| 9,10,11,12 | 30 x 15 x 12<br>76.2 x 38.1 x 30.5 | 15 x 15 x 0.75<br>38.1 x 38.1 x 1.9 | 30 x 9 x 5/32<br>76.2 x 22.9 x 0.4 | 30 x 24 x 12<br>76.2 x 61.0 x 30.5 | inches<br>centimeters |
| 13,14 | 30 x 20 x 12<br><br>76.2 x 50.8 x 30.5 | 14 x 19 x 0.5 (r)<br>13 x 21 x 1 (1)<br>35.6 x 48.3 x 1.3<br>33.0 x 53.3 x 2.5 | 30 x 4 x 5/32<br><br>76.2 x 10.2 x 0.4 | 30 x 24 x 12<br><br>76.2 x 61.0 x 30.5 | inches<br><br>centimeters |
| 15,16 | 30 x 20 x 12<br>76.2 x 50.8 x 30.5 | 14 x 19 x 0.5<br>35.6 x 48.3 x 1.3 | 30 x 4 x 5/32<br>76.2 x 10.2 x 0.4 | 30 x 24 x 12<br>76.2 x 61.0 x 30.5 | inches<br>centimeters |

| TESTS | CABINET BODY FRAME | SURFACE | FALSE FRONT | CABINET DOORS EACH DOOR |
|---|---|---|---|---|
| 1,2,3,4 | C,E | A | - | C |
| 5,6,7 | D | A | A | A,D |
| 8 | C,E | A | - | B |
| 9,10,11,12 | D | A | A | A,D |
| 13,14 | C,E | A | A | C (right)<br>B (left) |
| 15,16 | C,E | A | A | C |

A = 5/32-inch printed lauan plywood
B = 1-inch hollow core molded polystyrene
C = 1/2-inch printed particle board
D = 3/4 x 1-1/4-inch pine
E = 3/4 x 1-1/8-inch pine

NBS-114A (REV. 7-73)

| U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET | 1. PUBLICATION OR REPORT NO. NBSIR 75-788 | 2. Gov't Accession No. | 3. Recipient's Accession No. |
|---|---|---|---|

| 4. TITLE AND SUBTITLE | 5. Publication Date |
|---|---|
| Evaluation of the Fire Hazard in a Mobile Home Resulting from an Ignition on the Kitchen Range | February 1976 |
| | 6. Performing Organization Code |
| 7. AUTHOR(S) Edward K. Budnick and David P. Klein | 8. Performing Organ. Report No. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>NATIONAL BUREAU OF STANDARDS<br>DEPARTMENT OF COMMERCE<br>WASHINGTON, D.C. 20234 | 10. Project/Task/Work Unit No. 4926389<br>11. Contract/Grant No. |
| 12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)*<br>Office of Policy Development and Research<br>Department of Housing and Urban Development<br>Washington, D.C. 20410 | 13. Type of Report & Period Covered<br>Interim Report<br>14. Sponsoring Agency Code |

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*


A series of fire tests was conducted in a typical mobile home to evaluate the potential fire hazard resulting from an accidental ignition from cooking on the kitchen range. Specific attention was directed to (a) ease of ignition of the kitchen cabinets as a function of the clearance between the range and the underside of the cabinets with and without the presence of a metal hood and (b) flame spread following the ignition.

The tests, which used a preheated pan of cooking oil as an ignition source, were conducted in a mobile home kitchen area. The materials tested were printed lauan plywood, printed particle board, and molded polystyrene, representative of materials used in kitchen cabinet construction in mobile homes.

Under the test conditions employed, it was found that ignition of the kitchen cabinets occurred in all cases in which a metal hood was not used. The time to ignition of the materials was only slightly affected by the clearance between the specimen (cabinet bottom) and the range. A significant time delay or no ignition resulted from the installation of a metal range hood.

An additional problem area revealed by the tests was the ignition and burn-through of the partition directly behind the range.

Specific design recommendations based on test results are presented along with suggestions for further investigation.


17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)* Fire test; flame spread; kitchen cabinets; kitchen range; kitchen range hood; limited combustibility; mobile home.

| 18. AVAILABILITY [XX] Unlimited | 19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED | 21. NO. OF PAGES 27 |
|---|---|---|
| [ ] For Official Distribution. Do Not Release to NTIS<br>[ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13<br>[X] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151 | 20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED | 22. Price $4.00 |

USCOMM-DC 29042-P74